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Executive Summary

WP3.1 was focused on producing high-resolution surface parameter maps that support a better understanding of environmental patterns and climatic conditions across key archaeological sites in Greece. These maps are crucial for the preservation of cultural heritage sites, which are increasingly vulnerable to the impacts of climate change, including extreme temperatures, precipitation and wind conditions. The analysis of regional climatic patterns could help mitigate the environmental impacts on these ancient structures. By integrating climate data with historical site management strategies, we can enhance our capacity to preserve heritage for future generations.

1. Introduction

Archaeological sites in Greece hold historical, cultural and economic significance, playing a pivotal role in various activities and industries. These sites are essential not only for academic research and historical education but also for the tourism industry, which is a major economic driver in Greece. Millions of visitors from around the world visit these locations each year, contributing significantly to local economies.

It is evident that the preservation of archaeological sites is a crucial challenge especially in an era with rapidly changing climate conditions. To address this, climate analysis is vital as it helps assess and mitigate the impact of environmental factors on the preservation and stability of these invaluable cultural heritage locations. Archaeological sites are often exposed to harsh conditions, including temperature variations, precipitation and strong winds, which can accelerate the degradation of ancient structures and landscapes, potentially causing irreversible damage. By conducting thorough climate analysis, researchers and governmental entities can better understand local climate dynamics and identify potential threats, ultimately aiding in the protection of these sites (Nastos et al., 2021).

2. Regional Climatic Patterns (past & present climate)

Focusing on the Eastern Mediterranean region, and Greece in particular, an analysis was carried out examining key atmospheric variables based on dynamical downscaling (Politi et al., 2021; 2020). Specifically, the analysis of wind speed at 10 meters above ground level provides insights into near-surface wind conditions, critical for understanding local wind patterns and related impacts. Additionally, temperature at 2 meters above ground level was analyzed in an effort to understand conditions essential for assessing thermal comfort and climate variability. Finally, accumulated precipitation can provide valuable information on rainfall patterns, which are crucial for understanding hydrological cycles and potential flood risks in the region.

Beginning with wind at 10m, Greece experiences diverse wind patterns that vary significantly across its different regions due to its complex topography and geographical location in the Eastern Mediterranean (Figure 1). In the northern parts of Greece, particularly over Macedonia and Thrace, winds are generally moderate, influenced by weather systems. The presence of mountain ranges such as the Rhodope and Pindus acts as a barrier, shielding the interior from strong winds. However, the coastal areas along the northern Aegean Sea experience stronger winds, particularly in summer, as the Etesian winds funnel down from the north. In the south, especially over the Aegean Sea, wind speeds are higher. The Etesian

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winds dominate the Aegean during the summer months, blowing from the north. By contrast, the Ionian Sea, to the west of Greece, experiences milder winds as an average. The western and eastern regions of Greece show contrasting wind regimes due to the mountainous terrain. In contrast, the eastern regions along the Aegean coast and the islands experience stronger winds, especially during the Etesian season. In the Peloponnese and Crete, wind patterns can vary significantly between the mountainous interior, where winds are often disrupted, and the coastal areas, which are more exposed to stronger sea breezes and seasonal winds.

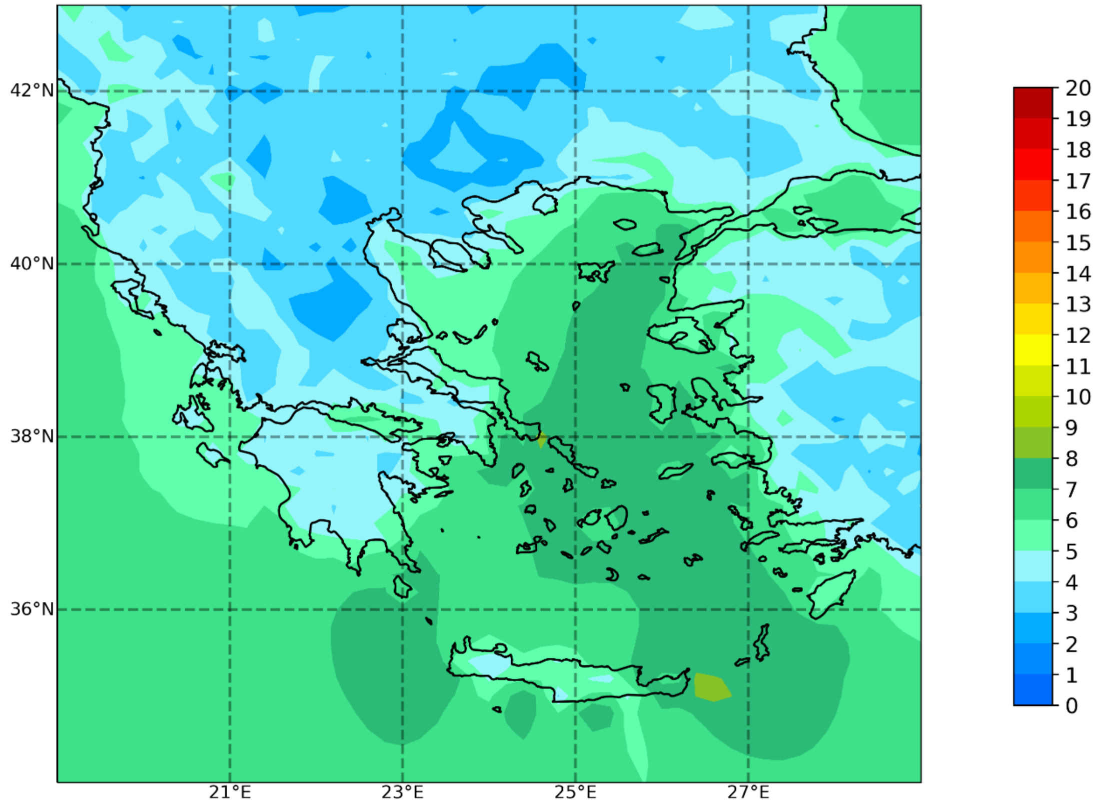

Figure 1: Mean annual wind speed at 10m (m/s).

In the winter months, Greece experiences stronger winds, especially in the northern and central parts, as well as over the sea (Figure 2). Higher wind speeds are especially met over the Aegean Sea, influenced by prevailing northerly winds. These winds are relatively strong, particularly in coastal and maritime regions, contributing to rough sea conditions.

By February, wind speeds increase slightly, continuing to affect the Aegean and central regions. This is the peak of winter winds, with conditions largely driven by cold air masses moving southward. Winds remain intense over the northern Aegean, but inland areas start to see a slight reduction as the winter progresses. The presence of low-pressure systems in the Mediterranean contributes to stronger winds.

In March, while the Aegean Sea still sees relatively strong winds, the overall intensity gradually becomes lower. March marks a transitional phase, with wind speeds beginning to drop across the country, particularly in the Ionian and western parts of Greece.

Moving into spring, wind speeds drop further in April. During this period, Greece experiences milder winds, particularly in the southern and western regions. The Aegean Sea continues to experience moderate wind activity, but much of the inland and western areas witness calmer conditions, as the influence of winter weather patterns wanes.

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By May, the average wind speed reduces even more, marking the beginning of calmer conditions, especially in the southern parts of the country. The Aegean remains windier than the rest of Greece, but the Ionian Sea and much of the mainland see a significant drop in wind intensity. This is typical for late spring as high-pressure systems start dominating the region.
Finally, in June, the overall average wind speed shows a slight increase as the Etesian winds begin to appear, particularly over the Aegean Sea. These northerly winds bring cooler and drier air, counteracting the rising summer temperatures. While the winds are not yet at their peak, June marks the onset of the seasonal winds that will become stronger during the summer months.

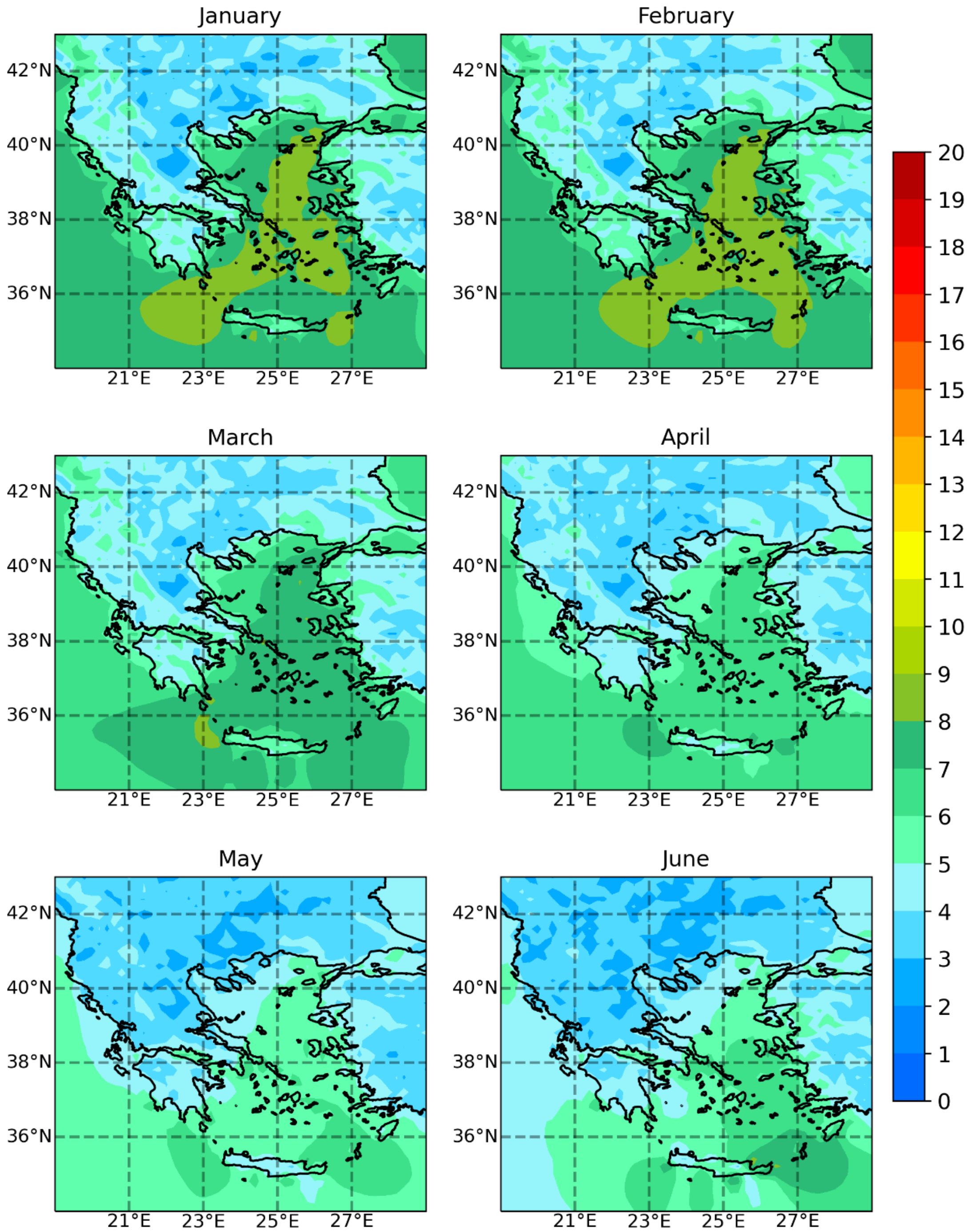

Figure 2: Mean monthly wind speed at 10m (m/s - January to June).

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In July, wind speeds increase significantly as the Etesian winds reach their peak. The Aegean Sea experiences strong northerly winds (Figure 3). These winds, often exceeding the seasonal average, play a crucial role in moderating summer heat and supporting maritime navigation, though they can also create hazardous conditions.

During August, the Etesian winds continue to dominate. Inland regions, particularly in the south, experience milder breezes as the strong winds remain concentrated over the sea. By September, the intensity of the Etesian winds begins to decline. This marks the transition toward autumn and while the Aegean Sea still experiences moderate winds, the rest of Greece, particularly the inland areas, sees a noticeable decrease in wind strength. October marks the early stages of the transition into the winter wind regime, with cooler air starting to push southwards. In November, the average wind speed rises as colder air from northern Europe begins to influence the region, signaling the start of the winter wind season. The Aegean Sea and northern Greece experience an increase in wind speeds as the region is affected by northerly and northwesterly winds. Inland regions begin to experience stronger winds as well, particularly in the northern and central parts of the country.

Finally, in December, the Aegean Sea experiences a return of strong northerly winds, and the coastal areas face rough sea conditions. These winds bring colder temperatures to Greece and contribute to an increase in wind activity, particularly in the central and northern parts of the country.

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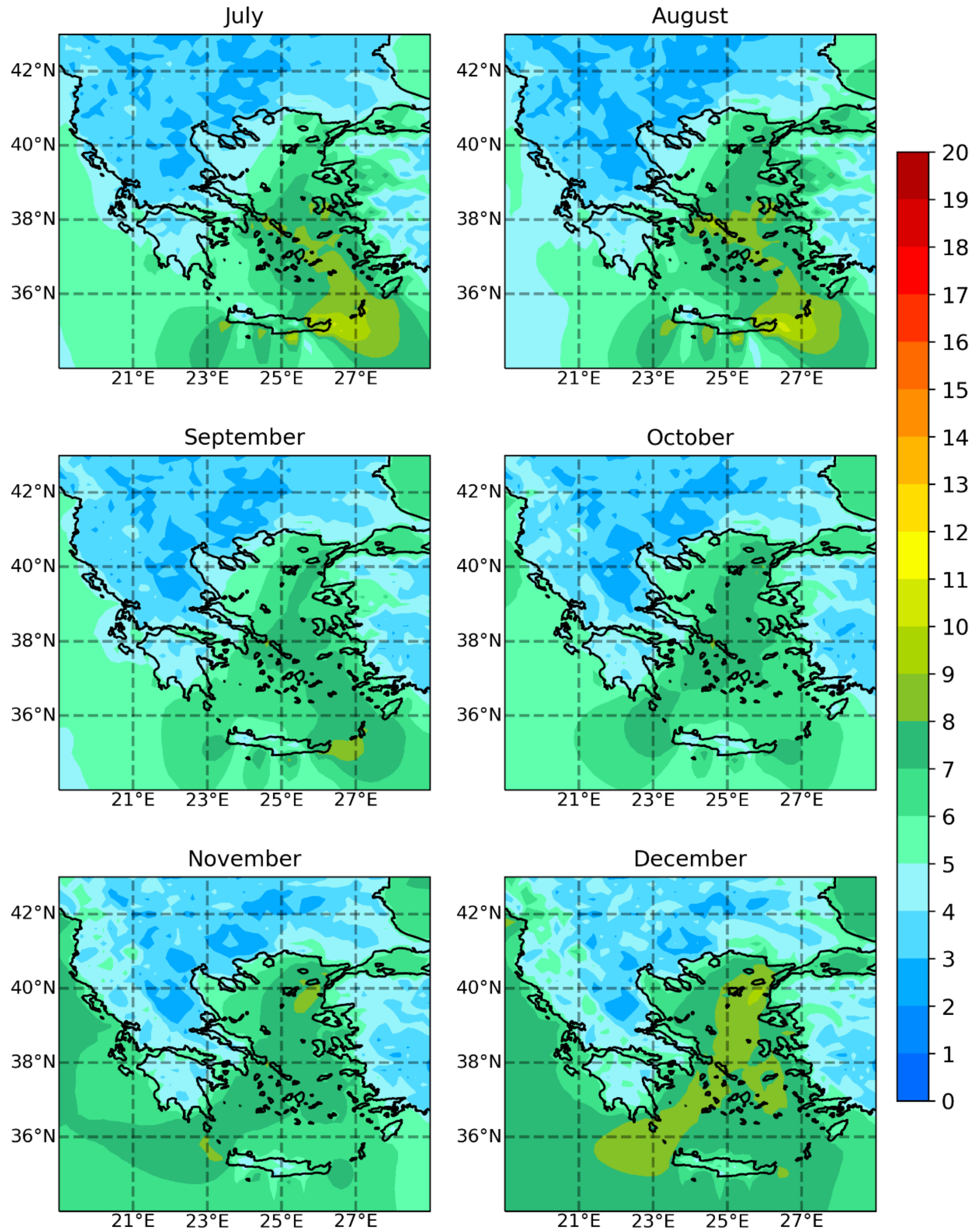

Figure 3: Mean monthly wind speed at 10m (m/s - July to December).

Focusing on temperature, the mean annual temperature across Greece reveals considerable variation due to the country's diverse topography and regional influences (Figure 4). In general, northern Greece experiences cooler temperatures, particularly in regions with higher altitudes such as Macedonia and Thrace. Here, the average annual temperature remains lower compared to the southern parts of the country, with mountainous areas like the Pindus range contributing to a marked reduction in temperatures. Coastal areas, particularly along the Aegean Sea, exhibit milder temperatures due to the moderating influence of the sea, though seasonal variations remain significant. Southern Greece and the islands of the Aegean and Crete enjoy higher annual average temperatures, with values often exceeding the

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national mean. The southern coastal regions and islands, being influenced by warmer air masses and sea breezes, experience a much milder climate throughout the year, contributing to the overall higher mean temperatures. Crete, in particular, shows consistently warmer conditions due to its southern latitude and maritime influence.

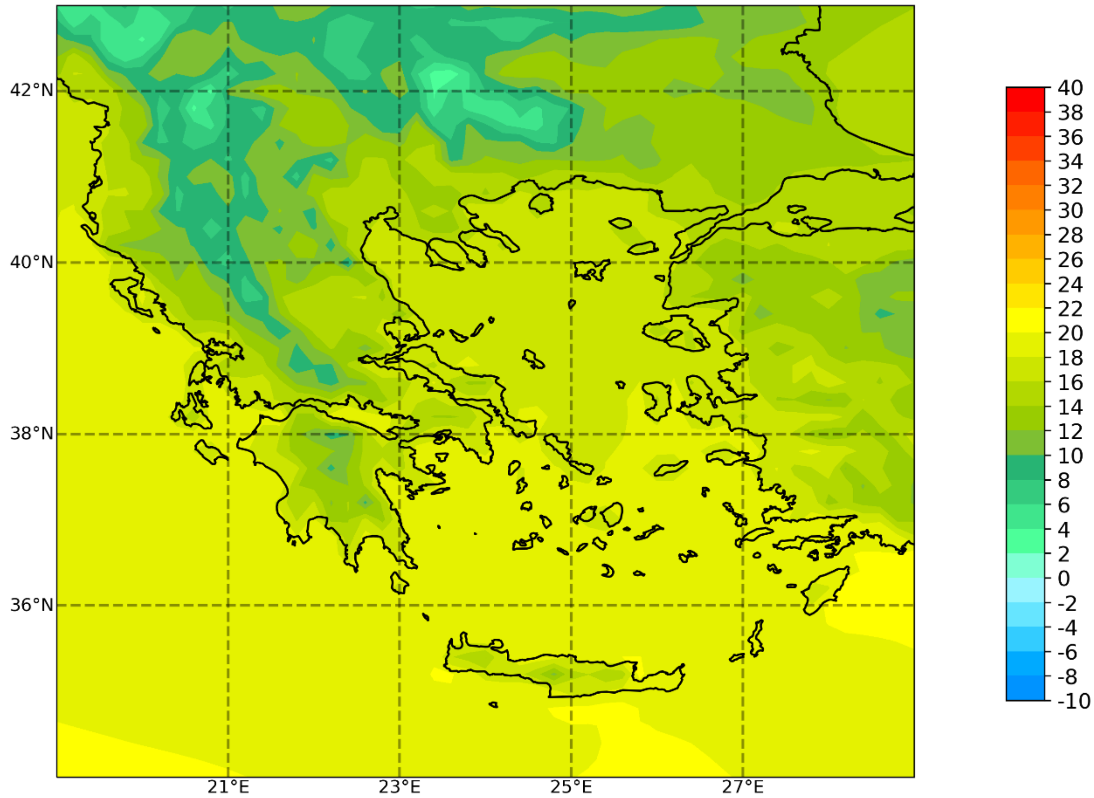

Figure 4: Mean annual temperature at 2m (°C).

In a monthly basis, the temperature patterns are quite diverse. In January, Greece experiences its coldest conditions (Figure 5). Northern regions, such as Macedonia and Thrace, along with mountainous areas, tend to be much colder, while southern coastal areas and the islands, including Crete, remain relatively mild. Moving into February, temperatures slightly rise to an average of 9.5°C, but winter still affects much of the country, particularly in the north and in higher altitudes.

By March, temperatures continue to increase. Early signs of spring are more evident in the southern regions, though cooler conditions persist in the north and in inland areas. In April, the country experiences more noticeable warming. Coastal areas and southern Greece begin to feel more spring-like conditions, while the north remains cooler. May brings further warming, marking the approach of summer, especially in southern Greece and the islands. In June, average temperatures reach 22°C. The southern parts of Greece and the islands, particularly Crete, experience much warmer weather, while inland and northern areas are also significantly warmer compared to spring.

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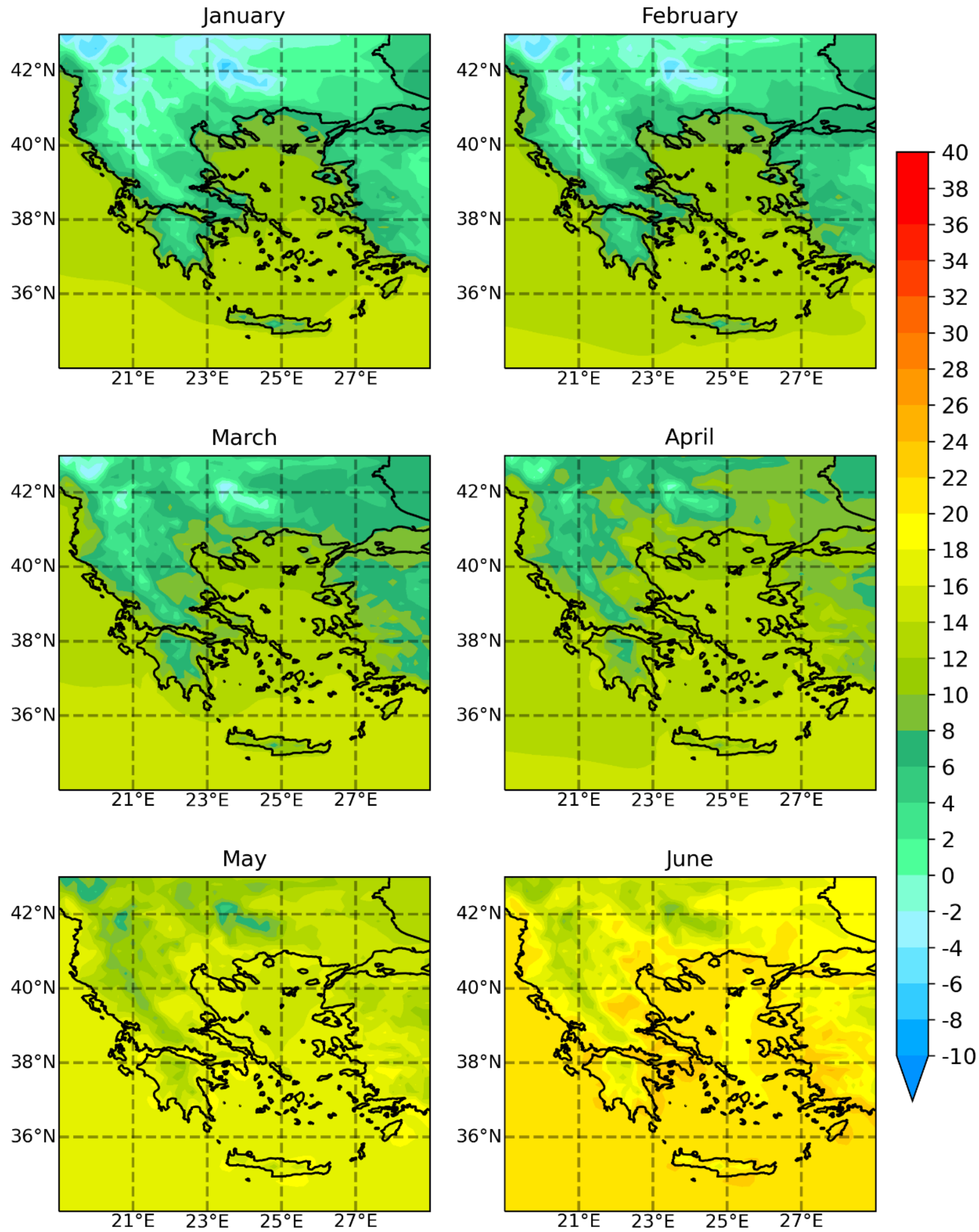

Figure 5: Mean monthly temperature at 2m (m/s - January to June).

July is one of the hottest months of the year, with the average temperature rising to 25°C (Figure 6). This is when the summer heat reaches its peak, especially in southern Greece and the Aegean islands. The heat continues into August, making it the hottest month of the year. Coastal areas and islands benefit from sea breezes, but inland regions, particularly in the south, experience high temperatures and dry conditions.

As September arrives, the transition to autumn begins. While the southern areas remain warm, northern regions begin to experience cooler weather. By October, temperatures drop further. The northern and mountainous areas become noticeably cooler, while southern regions and coastal areas still enjoy relatively mild weather. In November, the average

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temperature falls to 15°C, as colder air begins to spread across the country, signaling the approach of winter, particularly in northern Greece.
Finally, in December, the average temperatures drop to 12°C. The northern and mountainous regions are the coldest, while southern coastal areas, especially Crete, remain somewhat warmer, benefiting from the Mediterranean climate. These monthly temperature patterns highlight Greece's seasonal contrasts, shaped by its diverse geography and the influence of the surrounding seas.

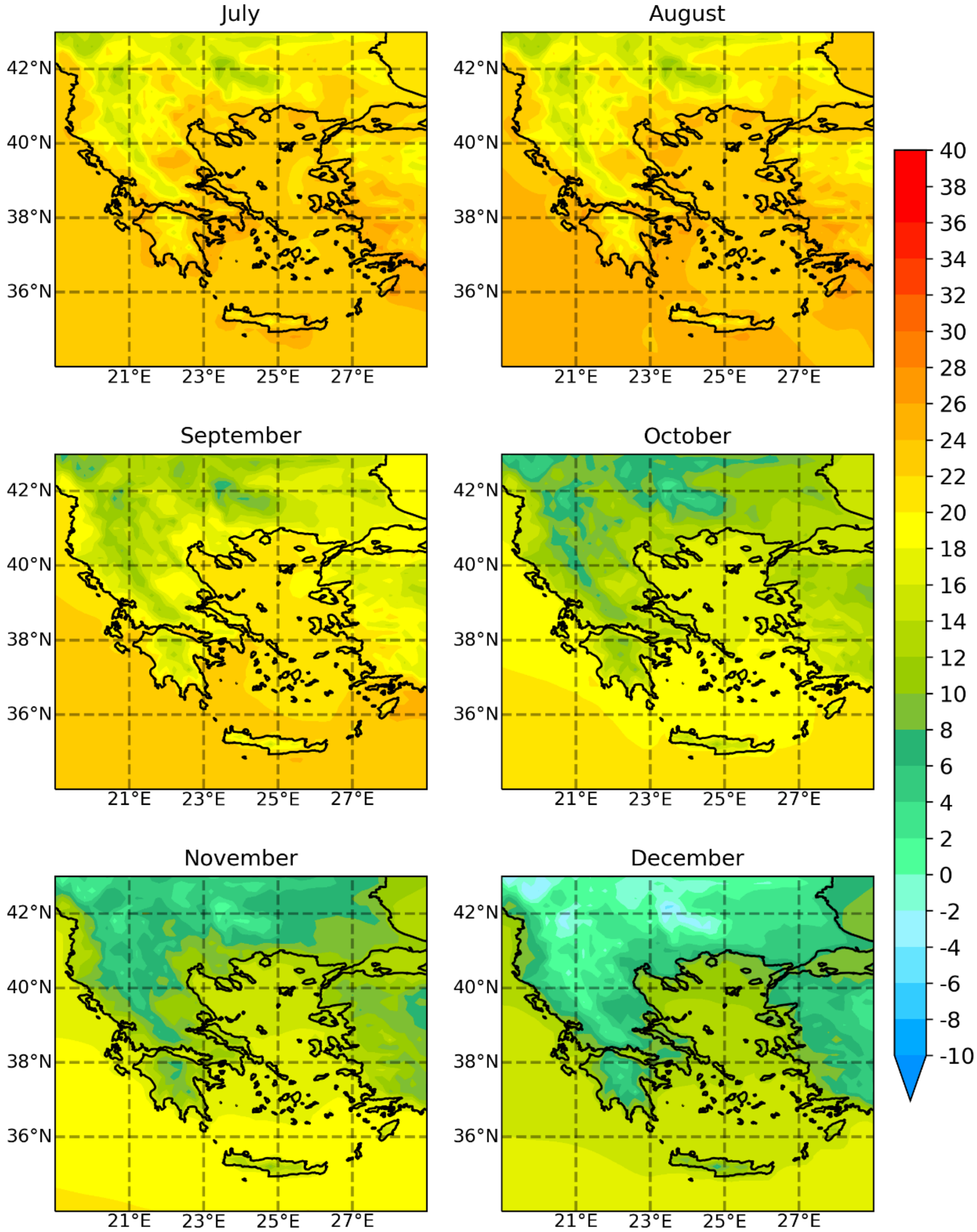

Figure 6: Mean monthly temperature at 2m (m/s - July to December).

Greece experiences significant regional variations in annual precipitation, influenced largely by its topography (Figure 7). The western parts of Greece, particularly in Epirus and along the Pindus mountains, are the wettest regions. These areas benefit from the orographic effect,

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where moist air from the Ionian Sea rises and cools as it encounters the mountains, leading to heavy rainfall. Annual precipitation in these areas frequently exceeds 1200 mm, with some high-altitude locations receiving even more. This makes western Greece one of the wettest regions in the country.
The northern regions of Macedonia and Thrace experience slightly lower but still substantial rainfall, with annual totals generally ranging between 800 and 1000 mm. These areas, particularly those close to mountain ranges, receive more precipitation during the winter months, when weather systems bring cold and wet conditions.
As we move into central and eastern Greece, including regions like Thessaly and parts of the Aegean coast, the annual precipitation levels drop to between 600 and 800 mm. Finally, the southern parts of Greece, particularly the islands such as Crete and the Cyclades, are much drier, receiving between 400 and 600 mm of rainfall annually. These areas are heavily influenced by the Mediterranean climate, characterized by dry, hot summers and wet winters. The southern regions experience significantly less rainfall compared to the western and northern parts of the country.

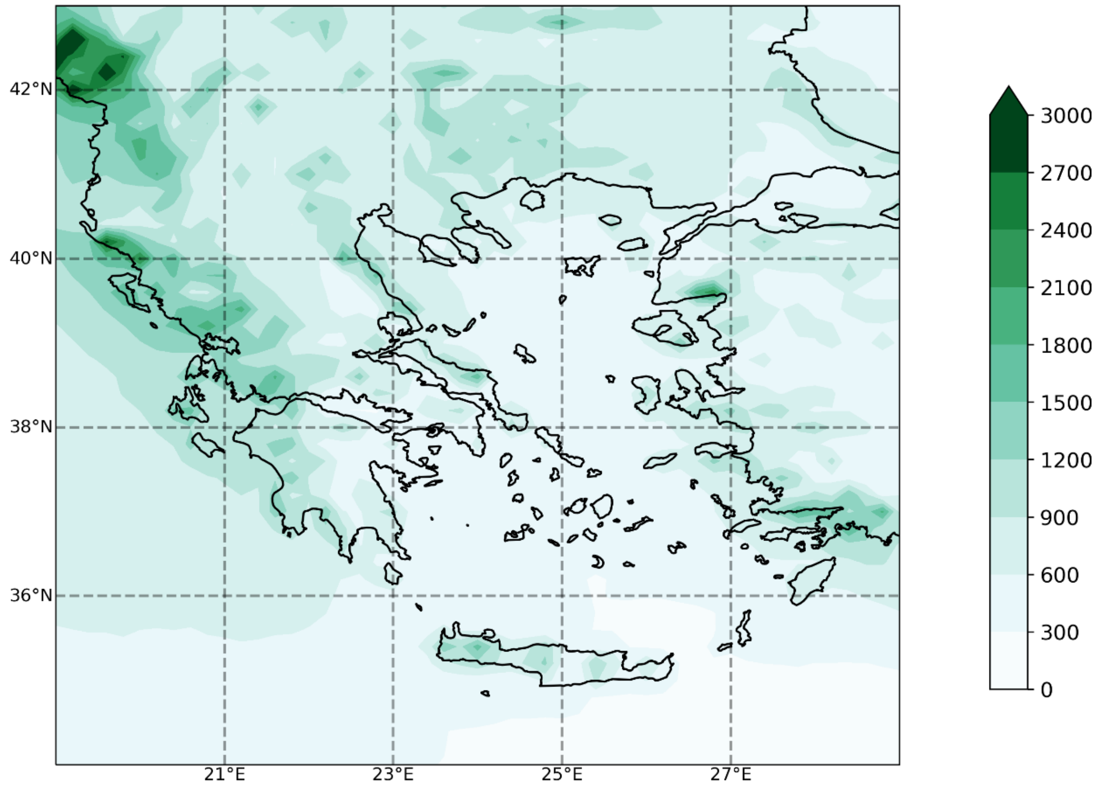

Figure 7: Mean annual accumulated precipitation (mm)

In January, Greece experiences the highest precipitation during the winter season (Figure 8). This is particularly evident in western Greece and mountainous regions, where rainfall is significantly higher due to the influence of moist westerly winds. February sees a slight reduction in rainfall, but remains a wet month, especially in the northern and western parts of the country.
As we move into March, the precipitation decreases further, marking the transition from winter to spring. Rainfall becomes more sporadic, and southern regions begin to dry out. April continues this trend and much of the country starts to experience drier conditions. In May, rainfall is quite low, particularly in southern and island regions. June brings slightly more

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rainfall than May but the dry summer season is already evident, especially in southern Greece and on the islands.

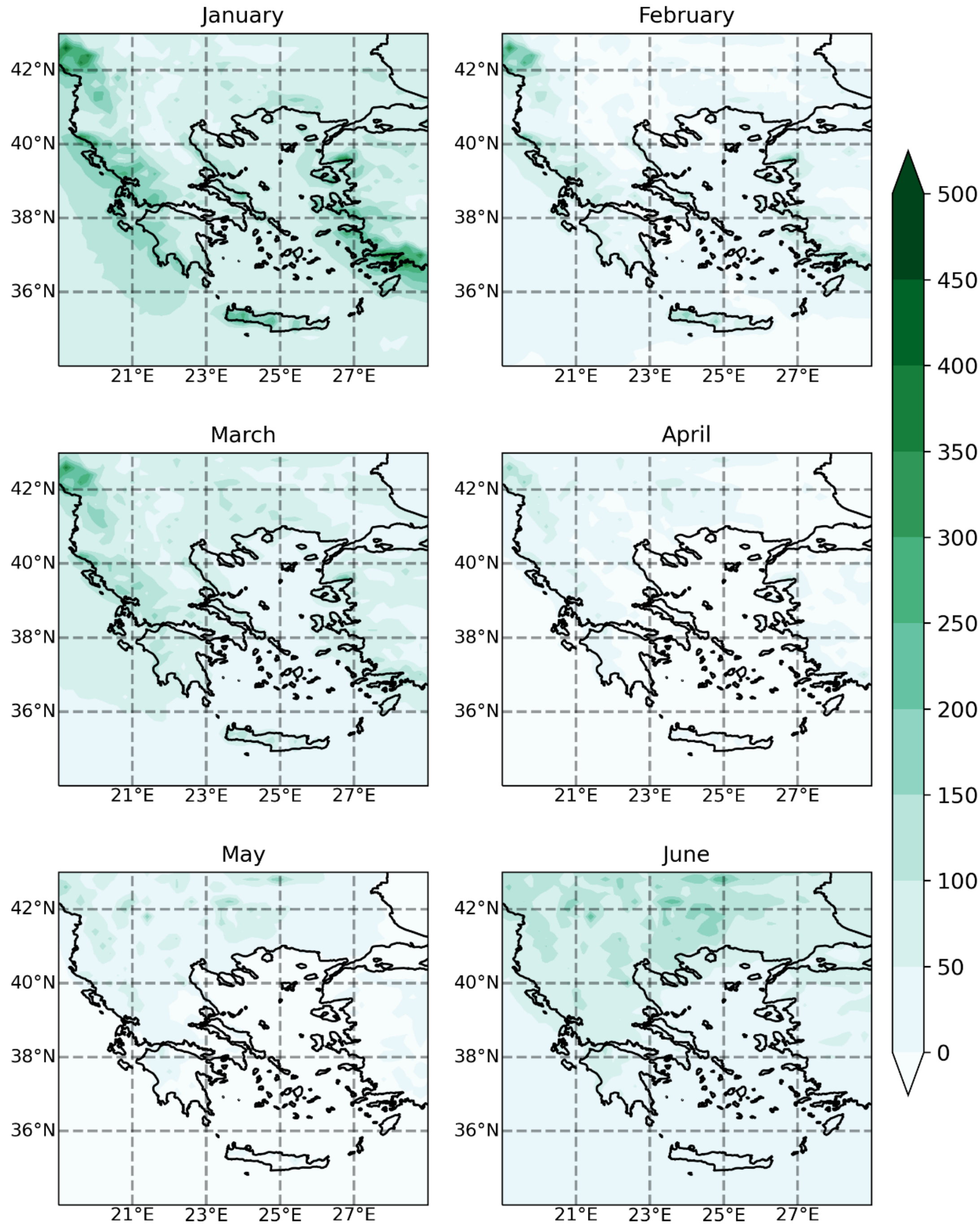

Figure 8: Mean monthly accumulated precipitation (mm – January to June).

July is the driest month of the year (Figure 9). Similarly, August remains dry, although localized thunderstorms can occasionally occur, particularly in northern Greece. In September, rainfall begins to increase again as the country transitions into autumn. Northern Greece and coastal regions start to receive more frequent rain showers. By October, the western regions, particularly Epirus, begin to receive heavier rains due to the approach of colder air masses. In November, precipitation increases further, as the country moves deeper into the autumn

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season. The mountains and western areas continue to experience the highest rainfall. Finally, December is the wettest month of the year, especially in the northern and western regions.

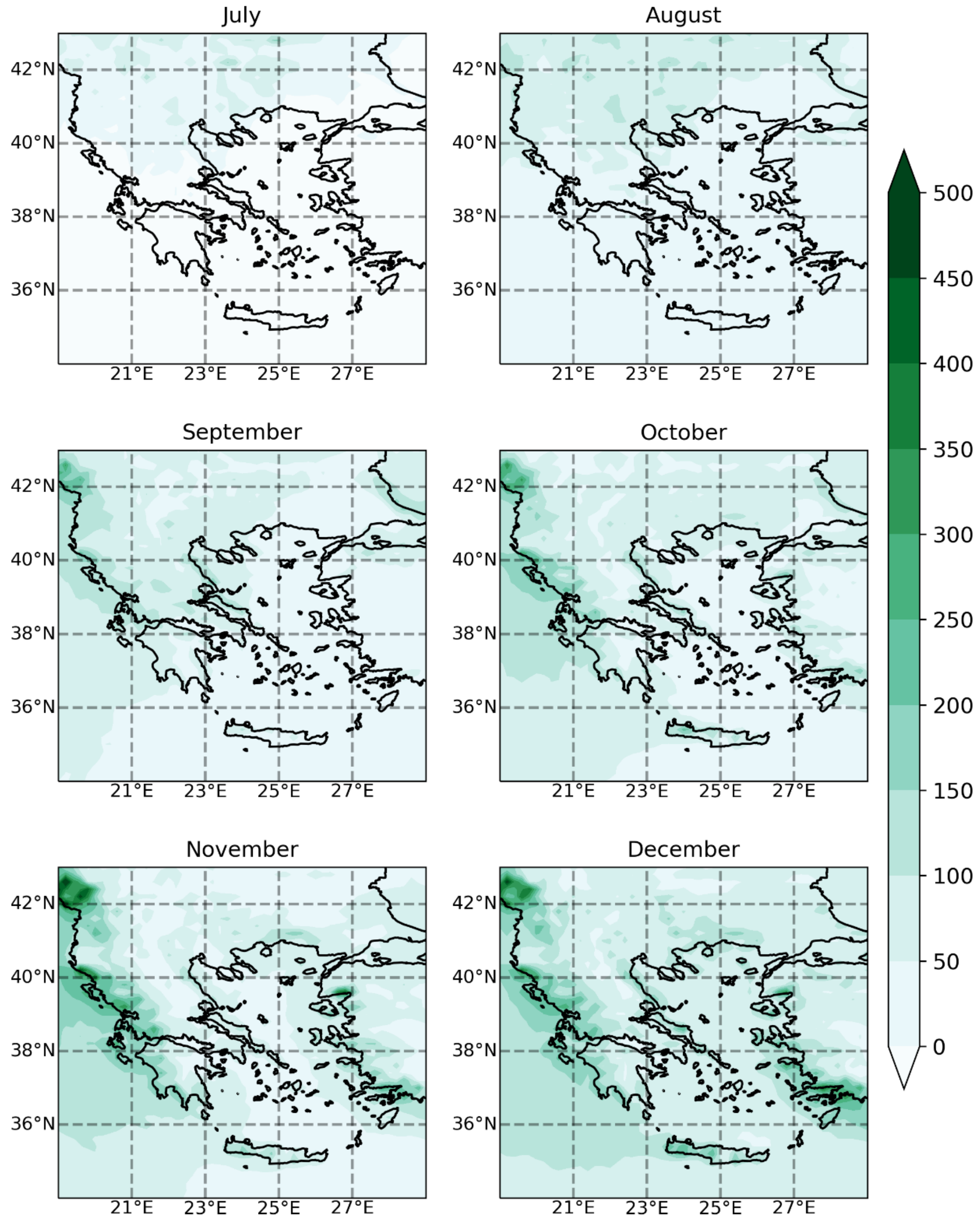

Figure 9: Mean monthly accumulated precipitation (mm – July to December).

3. Conclusions

The protection of archaeological sites in Greece is crucial and developing high-resolution surface parameter maps can be quite important towards this way. Atmospheric variables such as wind speed, temperature and precipitation are essential for assessing the impact of local climate conditions on the preservation of these sites. Wind speed analysis, revealed that certain regions, experience stronger winds due to the influence of Etesian winds, which could

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accelerate the wear and degradation of exposed sites. By understanding these wind patterns, targeted measures can be designed to protect vulnerable areas.
The temperature analysis showed a considerable regional variation, with northern mountainous areas generally cooler and southern coastal areas warmer. This variation is crucial as extreme temperatures, can cause thermal stress to structures. Additionally, the precipitation maps indicated that western Greece, influenced by moist air from the Ionian Sea, experiences significantly higher rainfall, which could increase the risk of water damage and erosion at archaeological sites. By integrating these climate insights into preservation strategies, we can enhance the capacity to safeguard Greece's cultural heritage.

4. References

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